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Kevin M. Kostelnik
James H. Clarke, Ph.D.
Jerry L. Harbour, Ph.D.

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Idaho National Engineering and Environmental Laboratory

A Sustainable System for Residual Hazards Management

Kevin M. Kostelnik [1,2], James H. Clarke, Ph.D.[1], & Jerry L. Harbour, Ph.D.[2]

[1] *Idaho National Engineering and Environmental Laboratory, USA.*
[2] *Vanderbilt University, USA.*

Abstract

Hazardous, radioactive and other toxic substances have routinely been generated and subsequently disposed of in the shallow subsurface throughout the world. Many of today's waste management techniques do not eliminate the problem, but rather only concentrate or contain the hazardous contaminants. *Residual hazards* result from the presence of hazardous and/or contaminated material that remains on-site following active operations or the completion of remedial actions. Residual hazards pose continued risk to humans and the environment and represent a significant and chronic problem that require continuous long-term management (i.e. >1000 years).

To protect human health and safeguard the natural environment, a sustainable system is required for the proper management of residual hazards. A sustainable system for the management of residual hazards will require the integration of engineered, institutional and land-use controls to isolate residual contaminants and thus minimize the associated hazards. *Engineered controls* are physical modifications to the natural setting and ecosystem, including the site, facility, and/or the residual materials themselves, in order to reduce or eliminate the potential for exposure to contaminants of concern (COCs). *Institutional controls* are processes, instruments, and mechanisms designed to influence human behavior and activity.

System failure can involve hazardous material escaping from the confinement because of system degradation (i.e., chronic or acute degradation) or by external

intrusion of the biosphere into the contaminated material because of the loss of institutional control.

An ongoing analysis of contemporary and historic sites suggests that the significance of the loss of institutional controls is a critical pathway because decisions made during the operations/remedial action phase, as well as decisions made throughout the residual hazards management period, are key to the long-term success of the prescribed system. In fact, given that society has become more reliant on and confident of engineered controls, there may be a growing tendency to be even less concerned with institutional controls.

Keywords: institutional controls, residual hazards, waste management, stewardship, engineered barriers.

1 Introduction

A negative result of energy production, mineral extraction, national defence, and industrial operations is environmental degradation associated with the management and disposal of waste and chemical by-products. These environmental problems are enormous and affect international, national, state, and local entities Butterworth [1], USDOE [2], USDOE [3]. The United States is addressing these problems by enforcing a variety of environmental regulations. The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) [4], GI [5] establishes the framework for the federal response to the release of hazardous substances that endanger public health or the environment. The Resources Conservation and Recovery Act (RCRA) GI [5], [6] minimizes future pollution that may result from solid waste landfills. And, the Small Business Liability Relief and Brownfields Revitalization Act (Brownfield) USEPA [7] focuses on redevelopment of abandoned, idle, or under-utilized environmentally-contaminated industrial and commercial facilities.

In many situations contaminants will remain at these sites after environmental remediation is completed. These contaminants include waste or contaminated materials left in place or disposed of on-site as well as residual contamination of soils, facilities, surface water and groundwater. *Residual hazards* are associated with the presence of hazardous and/or contaminated material that remains on-site following active operations or the completion of remedial actions. These contaminants and the associated residual hazards pose continued risk to humans and the environment and represent long-term liabilities (i.e. 100's-1000's of years) that require continuous management.

2 Management Systems

Many of today's remedial operations tend to treat certain contaminants and consolidate the remaining contaminated materials on-site. Management strategies for residual hazards, therefore, typically involve the containment of contaminated materials into near-surface contaminant isolation facilities. These facilities are designed for the long-term control of contaminants (i.e. radioactive, organic, inorganic, etc.) as well as the mitigation of their associated hazards (i.e. radiation, radon emanation, contaminated leachate migration, fire and explosion potential, etc.). The objective of this structure is to maintain isolation of these contaminants for a specified timeframe or until the contaminants no longer present unacceptable risk to humans or the environment. If the contaminants decay and the associated site risk is reduced to acceptable levels, the site could potentially be released for unrestricted use at that time as illustrated in Figure 1.

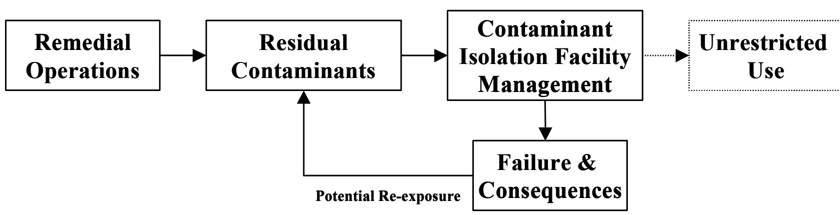

Figure 1: Residual hazards management conceptual model.

This situation, however, does not always occur. Waste management experience is beginning to show that actual performance often deviates from the plan NRC [8], USEPA [9], USDOE [10], USDOE [11]. These deviations, if not rectified, can negatively affect facility performance. In the worst case, deviations can lead to facility failure whereby receptors are re-exposed to the residual contaminants. This re-exposure may be the result of a.) System degradation or egress of contaminants from the facility, or b.) External intrusion or ingress of the biosphere into the residual contaminants.

3 System Approach

Recent studies recommend a 'systems approach' for improving the long-term isolation of hazardous materials INEEL [12], NRC [13]. For a contaminant isolation system to remain sustainable our research suggests that three general functions need to be continually fulfilled. These functions include a.) Maintaining active Remedial Processes, b.) Maintaining the Engineered Barriers, and c.) Fulfilling Institutional Responsibilities.

Active remedial processes are commonly associated with the ongoing treatment of contaminated groundwater or a treatable source-term in the vadose zone. These processes require continued operational support; such as power, equipment maintenance, sample management, etc. to ensure they perform as expected.

Engineered barriers are structures designed to modify the natural setting. Contaminant isolation facilities typically consist of engineered components; including surface covers and caps, stabilized wasteforms, monitoring systems and subsurface barriers, require periodic maintenance to ensure they remain effective Clarke *et al* [14], Benson *et al* [15].

Institutional responsibilities include conventional institutional controls as well as other required functions designed to influence human behavior and activity. Institutional controls most often used in the United States include government controls such as local zoning and groundwater use restrictions and property-based controls such as deed restrictions and covenants Borinsky [16], Gaspar and Burik [17]. Additional responsibilities include maintaining the security of the site from inadvertent or intentional intrusion, maintaining financial security of the site and associated functions, maintaining a multi-generational awareness within the local community, maintaining emergency/contingency plans and performing emergency actions when applicable, maintaining information/records, evaluating the surrounding environment/ecosystem, and continually assessing the performance of the system and identifying areas for improvement.

4 Adaptive Management

The challenge in maintaining long-term containment of hazardous constituents is a complex spatial and temporal problem. Figure 2 attempts to illustrate this challenge. Environmental settings, common engineered barriers and controls, and the associated monitoring techniques are shown.

Site-specific characteristics, taken into account during the design phase of the system, continue to evolve over time and will therefore influence the performance of the system throughout its life. These changes can result in either positive or negative impacts depending on the ongoing management approach.

To better account for these temporal changes an ‘adaptable’ system is required for the long-term management of residual hazards NEPI [18]. This adaptive approach requires the coupling of acceptable remedies, performance monitoring, and sustainable controls consistent with desired and potential land-use.

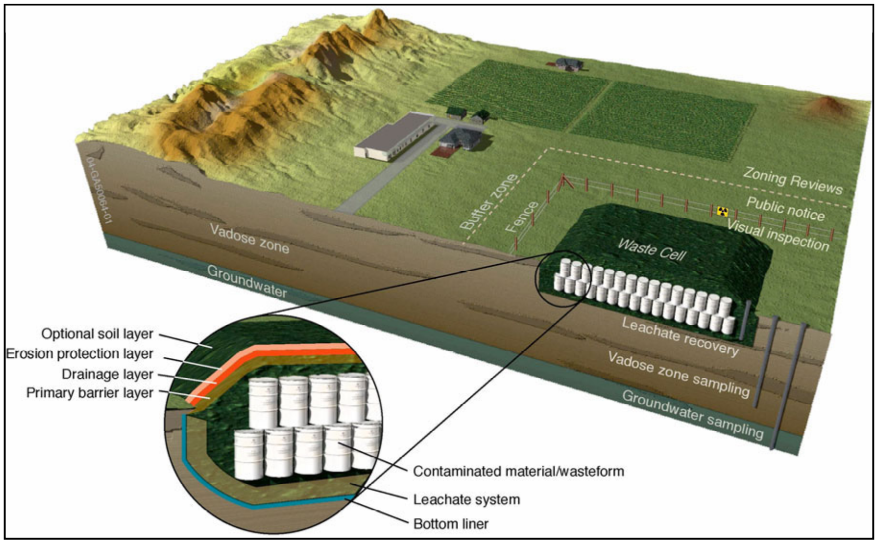

Figure 2: Residual hazards management systems view.

5 Proactive Monitoring

An adaptive management approach requires the continuous monitoring of the system's performance. This includes recognition that the system will interact with the natural environment as well as current and future societies. These various interactions suggest that a variety of monitoring techniques will be required.

Periodic visual inspection of the facility's physical features (e.g. cell cover, access restrictions, etc.) often serves as a primary qualitative monitoring technique. These inspections are useful in identifying events such as erosion, bio-intrusion, subsidence, material degradation, infiltration, seepage, deliberate intrusion, vandalism and property restriction violations.

Affirmative monitoring and enforcement actions are also required for maintaining institutional responsibilities. Proactive monitoring measures should include continual assessment (i.e. annually, 5-year reviews, etc.) of demographic patterns, regional land-use changes, zoning change requests, periodic Notice, public involvement and awareness, legal authority, information collection, integration and reporting, emergency preparedness and financial solvency.

6 Conclusion

A sustainable system for the management of residual hazards is required to maintain long-term isolation of residual contaminants. Such a system should involve the integration of remedial processes, engineered barrier maintenance and institutional responsibilities. An adaptive systems approach can improve the site steward's ability to minimize the negative effects of external influences and thus maintain the long-term performance of the system.

References

[1] Butterworth, J.S., *Contaminated Land.* The Safety & Health Practitioner, 2000. **18**(3): p. 50-53.

[2] USDOE, *A Report to Congress on Long-Term Stewardship, Volume 2 - Site Summaries*. 2001, U.S. Department of Energy, Office of Environmental Management, Office of Long-Term Stewardship: Washington D.C.

[3] USDOE, *A Report to Congress on Long-Term Stewardship, Volume 1 - Summary Report*. 2001, U.S. Department of Energy, Office of Environmental Management, Office of Long Term Stewardship: Washington D.C.

[4] *Comprehensive Environmental Response, Compensation, and Liability Act*. CERCLA 1994.

[5] GI, *Environmental Law Handbook*. 2001: Government Institutes.

[6] *Resource Conservation and Recovery Act*, in *US Code, Title 42, Chapter 82, Subchapter I, Section 6901*. RCRA 1976.

[7] USEPA, *Small Business Liability Relief and Brownfields Revitalization Act*. 2002, U.S. Environmental Protection Agency.

[8] NRC. *Barrier Technologies for Environmental Management - Summary of a Workshop*. in *Barrier Technologies for Environmental Management*. 1997.

[9] USEPA, *Evaluation of Subsurface Engineered Barriers at Waste Sites*. 1998, U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.

[10] USDOE, *Plant Encroachment on the Burrell, Pennsylvania, Disposal Cell: Evaluation of Long-Term Performance and Risk*. 1999, U. S. Department of Energy: Grand Junction, CO.

[11] USDOE, *Durango, Colorado Disposal Site, Annual Inspection Report*. 1999, U.S. Department of Energy, Long-Term Surveillance and Maintenance Program: Grand Junction, CO.

[12] INEEL, *Long-Term Stewardship Science and Technology Roadmap*. 2003, Idaho National Engineering and Environmental Laboratory: Idaho Falls, ID.

[13] NRC, *Long-Term Institutional Management of U.S. Department of Energy Legacy Waste Site*. 2000, Committee on the Remediation of Buried and Tank Wastes, National Research Council: Washington D.C.

[14] Clarke, J.H., M.M. MacDonell, E.D. Smith, R.J. Dunn, and W.J. Waugh, *Engineered Containment and Control Systems: Nurturing Nature.* Journal of Risk Analysis, 2004. **accepted for publication**.

[15] Benson, C.H., W.H. Albright, A.C. Roesler, and T. Abichou. *Evaluation of Final Cover Performance: Field Data from the Alternative Cover Assessment Program*. in *Waste Management*. 2002. Tucson, AR.

[16] Borinsky, S.C., *The Use of Institutional Controls in Superfund and Similar State Law.* Fordham Environmental Law Journal, 1995. **7**(1995-1996): p. 54.

[17] Gaspar, C. and D.V. Burik, *Local Government Use of Institutional Controls at Contaminated Sites - Working Draft*. 1998, International City/County Management Association: Washington D.C. p. 50.

[18] NEPI, *Rolling Stewardship: Beyond Institutional Controls - Preparing Future Generations for Long-Term Environmental Cleanups*. 1999, National Environmental Policy Institute: Washington D.C. p. 51.